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EVALUATION IN ILLINOIS OF FOUR INERT DUSTS ON STORED SHELLED CORN FOR PROTECTION AGAINST INSECTS -- A PROGRESS REPORT

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CAUTION

If pesticides are handled, applied, or disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, and pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use pesticides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

NOTICE

This is a progress report of the first year of a test with diatomaceous earth, silica aerogel, and malathion to determine their effectiveness in controlling insects in aerated shelled corn stored in a commercial corn-growing area.

At the present time, U.S. Department of Agriculture and Food and Drug Administration clearances have not been established for the use of silica aerogel for the prevention of insect infestation in stored grain. The tests reported herein were exploratory studies to develop information on performance. The silica aerogel treatments should not be used unless appropriate clearances are established.

Diatomaceous earth may be applied to stored grain for insect control in accordance with label instructions approved by USDA. GR Instruction 918-6 Aux. 1, dated May 9, 1963, (18) from the Grain Division, Consumer and Marketing Service (formerly Agricultural Marketing Service), provides instructions to licensed grain inspectors for grading grain containing diatomaceous earth. An applicant for inspection who has grain which contains or appears to contain diatomaceous earth and who wishes to have the grain graded as though it did not contain an unknown foreign substance, may file a written application with the grain inspector for an examination for diatomaceous earth.

Malathion has a tolerance of 8.0 p.p.m. when applied to stored grain for insect control and may be used in accordance with label instructions.

Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty and does not signify that the product is approved to the exclusion of other comparable products.

ACKNOWLEDGMENTS

This is a report on research conducted by a number of individuals or groups. Roy Tipton, Wilbur F. Bauer, and Marvin Windhorn of the Stored-Grain Insects Laboratory, Watseka, Ill., assisted in applying the dusts and in recording results. The physical aspects of the study concerning the grain handling, and the installation and maintenance of the grain bins and aeration systems, were conducted by Herman F. Mayes, agricultural engineer, Transportation and Facilities Research Division, Agricultural Research Service, Watseka, Ill. Malathion residue analyses were conducted by the Stored-Product Insects Research and Development Laboratory at Savannah, Ga. The funds, corn, and facilities for conducting this work were furnished by the Commodity Credit Corporation, U.S. Department of Agriculture.

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EVALUATION IN ILLINOIS OF FOUR INERT DUSTS ON STORED SHELLED CORN FOR PROTECTION AGAINST INSECTS -- A PROGRESS REPORT

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SUMMARY

Thirty 3,250-bushel circular metal standard USDA bins, each containing about 3,000 bushels of shelled yellow corn, were used in this study. Each bin had a vertically placed aeration system. Two diatomaceous earths, two silica aerogels, and malathion were used to treat the corn. Each treatment was used on the corn in five bins; the other five bins were not treated. The diatomaceous earths were applied at a rate of 196 pounds per 1,000 bushels and the silica aerogels at 28 pounds per 1,000 bushels; a 57-percent malathion emulsifiable concentrate was applied at 1 pint per 1,000 bushels.

The corn was treated and artificially infested with rice weevils and red flour beetles as it was unloaded from trucks and augered into the bins during August 1963. Samples were taken before treatment for insect counts and determination of commercial grade. After treatment, samples were taken for the determination of live insects, commercial grade, degree of insect damage, residue analyses (malathion only), and laboratory bioassay (mortality, reproduction, emergence, and repellency to flour beetles and rice weevils).

All treatments effectively controlled the insect populations for a period of 1 year. All inert dust-treated samples contained insects during the first 3 months but relatively few thereafter. Rice weevils were predominant.

All of the inert dust treatments lowered the test weight of the corn. The moisture readings were lowered due to the physical action of the dusts. The malathion-treated corn and the untreated check showed no alteration in the grade factors. The corn treated with silica aerogel was graded "sample grade" because of the dust, which was considered a foreign substance by the grader.

Insect damage to the corn did not increase in the corn treated with inert dust or malathion. There was an increase in insect damage in two of the five untreated checks.

Chemical analysis for malathion indicated that about one-fifth (approximately 2 p.p.m.) of the malathion applied was present 1 month after treatment. This residue remained virtually constant throughout the remainder of the observation period.

In laboratory bioassay tests, the malathion was superior to dust treatments in causing mortality, inhibiting reproduction, and reducing the number of emerging test insects. In other laboratory bioassay tests the corn treated with inert dust showed considerable repellency to the test insects.

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[1] These laboratories are field stations of the Stored-Product Insects Research Branch, Market Quality Research Division, Agricultural Research Service, U.S. Department of Agriculture.

W. L. Berndt is a former employee of the Manhattan laboratory. He is now with the Cooperative Extension Service of South Dakota State University, Brookings, S. Dak.

The diatomaceous earths exhibited higher repellency for a longer period than the silica aerogels. The malathion did not exhibit repellency through the observation period.

Use of the dusts had a detrimental effect on speed of movement of the grain, on the air-cooled gas engines that activated the augers, and on ease of manually probing the grain.

BACKGROUND AND PURPOSE OF THE WORK

One of the early methods of combating stored-grain insects was the use of inert dust. The use of ashes is an ancient practice in India (14).[2] One author (11) states, "The fact that certain native tribes still (1944) mix wood or aloe ash with their grain indicates that this method had been in vogue for many centuries in South Africa..." Pruthi and Singh (14) discussed three materials that were being used in 1948 in other parts of the world. These are katelsousse, a mixture of about 83 percent calcium phosphate and 17 percent sulfur in the Middle East; vivianite, a hydrated ferrous phosphate in Russia; and naaki, a pure quartz sand, ground to different grades of fineness in Germany.

A considerable amount of work has been conducted with inert substances for the control of insects. A recent extensive review of past studies has been conducted (2). The literature on the use of diatomaceous earth to control stored-grain insects is quite extensive, but that on silica aerogel is limited.

Adult bean weevils were dusted directly with amorphous silica (from diatoms) with high mortality (3). When rice weevils were dusted directly with amorphous silica, 50 percent mortality resulted in 4 days and 100 percent mortality in 8 days (4). Eight ounces of diatomaceous earth mixed with 200 pounds of peas and beans effectively controlled the bruchid Acanthoscelides obtectus (Say) (13). Diatomaceous earth, 0.5 percent by weight, when applied to beans to control A. obtectus, gave high mortality of the insect and was more effective than bentonite, kaolin, or talc (15). Maize stored in bags was treated with diatomaceous earth at 140 pounds per 1,000 bushels. The resulting damage after 6 months was 9 percent, after 9 months 17 percent, and after 18 months 20 percent (10). In a recent study, 100 percent mortality of rice weevils was obtained in wheat at 14 percent moisture content after 2 weeks' exposure at a dosage rate of 7 pounds of diatomaceous earth per ton. Red flour beetle mortality was only 5 percent (2). Laboratory tests with diatomaceous earth applied at the rate of 4, 6, and 8 pounds per ton of wheat indicated that the 4-pound dosage would prevent infestation for 6 months, the 6-pound dosage for 9 months, and the 8-pound dosage for 12 months or more (16).

The minimum effective dosage of silica aerogel was found to be 0.05 percent by weight in 14-percent-moisture wheat (5). Silica aerogel applied to stored 12-percent-moisture sorghum was effective at 0.05 percent by weight (6). In recent studies where silica aerogel was deposited on filter paper, the insects died quickly. The studies indicated that impregnated paper may open the way for development of insect-proof food packages (19).

An amendment to the commercial grain grading standards allows that certain grains can now be treated with diatomaceous earth (18). Also, diatomaceous earth can be applied directly to certain grains on a tolerance exempted basis (7).

It is pointed out that inert dust is relatively nontoxic to warmblooded animals and does not lose its effectiveness through chemical decomposition (19). Carlson and Ball (2) stated that diatomaceous earth is "without known insect resistance buildup."

On the other hand, excessive atmospheric dust, limitations on the free-running properties of grain, and difficulty in assessing grain quality appear to be the primary objections (16). Two of these disadvantages are also mentioned by Parkin (12), who was concerned with the limiting of the "free-running properties" of the grain and with the "intensified dust clouds." The silica aerogel dust is highly irritating when breathed. Therefore, workmen treating products with it need protection from breathing the dust (5). The dust may also affect the appearance of the grain. It may lower the test weight and thus lower the commercial grade of the grain.

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[2] Underscored numbers in parenthesis refer to Literature Cited, pages 19 and 20.

In this study, two diatomaceous earths, Perma-Guard and Kenite, and two silica aerogels, Cab-0-Sil and SG-68, were tested. The dosage level of the diatomaceous earths is that recommended on the manufacturers' labels. The dosage of the silica aerogels was based on laboratory work conducted by Cotton and Frankenfeld (5) and King, Morrison, and Sundman (6), who found that 0.05 percent by weight of the dust was effective in various stored grains.

The primary objective of the study reported here was to determine the effectiveness of several inert dusts in controlling an existing infestation and preventing subsequent reinfestation of insects in stored shelled corn.

Secondary objectives were to:

1. Determine the effect of each treatment on the commercial grade factors.
2. Determine if there was a loss in the ability of the treatments to produce insect mortality through the storage period.
3. Determine the degree of insect damage that occurred after each treatment.
4. Determine if the treatments caused the grain to be repellent to insects and, if so, if repellency decreased with time.

TECHNIQUES AND MATERIALS

Storage Structures and Corn Handling

This study was initiated in August 1963 at the Watseka, Ill., experimental binsite. Shelled yellow corn was treated and stored in 30 aerated 3,250-bushel circular metal standard USDA bins. The bins are 16 feet in height and 18 feet in diameter. The corn had been stored on the farm as ear corn since its harvest in 1962. In 1963, it was shelled on the farm and trucked to a commercial elevator to be blended for uniformity. It was then trucked to the binsite and treated as it was augered into the bins. The corn was moved into the bins with a 45-foot-long Andrews auger, which was 9 inches in diameter (fig. 1).

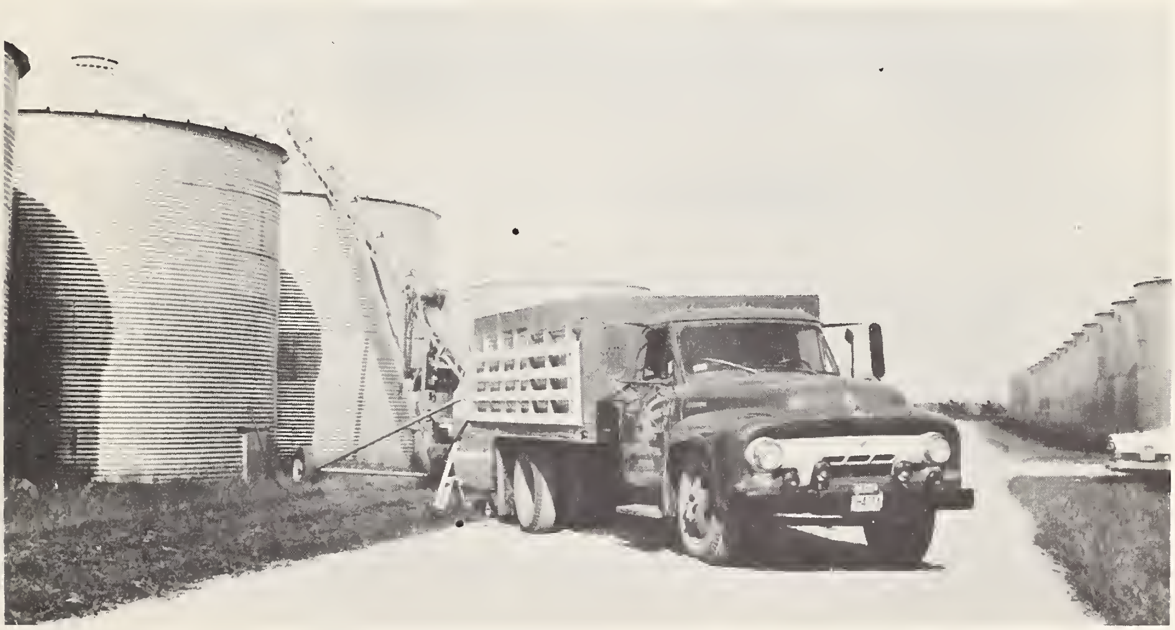

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Figure 1.--Unloading and augering corn into a 3,250-bushel bin.

Aeration

Aeration units were in place before the corn was loaded into the bins. The ducts were hung with chains from the roof opening and wired at the bottom of the bin to prevent movement when the grain was loaded into the bins. A 12-inch cone-shaped grain cover was suspended over the duct opening to keep the corn out of the duct and to help distribute the grain.

Each aeration duct was 12 feet long and 8 inches in diameter. It was fabricated of 22-gage steel. Six feet of the duct was perforated, and 6 feet was nonperforated. When the bin was filled, all of the perforated section and about 3 feet of the nonperforated section of the duct was buried in the corn. A 100-c.f.m. fan was inserted into the end of the supply duct that was sticking out of the corn. The fans were turned on the first week in September and operated continuously during the observation period.

Infestation of the Corn

The corn was artificially infested by adding 2 gallons of infested corn to each 300-bushel truckload of corn. It was estimated that the 20 gallons of infested corn added to each 3,000-bushel bin contained about 3,200 adult rice weevils, 3,200 immature rice weevils, and about 1,500 larva and adult red flour beetles.

Characteristics of the Inert Dusts

Characteristics of the Perma-Guard, a diatomaceous earth, as furnished by the company from whom it was purchased, were as follows:

Moisture	percent	1.5 to 3.0
Dry density	lb./cu. ft.	20.0 to 24.0
Retained on 325-mesh screen	percent	9.0 to 13.0
Particle size	microns	0.1 to 40.0
Silica (SiO_2) guaranteed	percent	More than 80.0
Cristobalite	percent	Less than 1.0
Surface area	sq. cm./gram	20,000 to 30,000
Brightness	photovolt	60 to 75

The characteristics of Kenite 2-I, a diatomaceous earth, furnished by the company from whom it was purchased, were as follows:

Moisture	percent	8
Retained on 200-mesh screen	percent	Less than 3
Retained on 325-mesh screen	percent	Less than 10
Silica (SiO_2)	percent	88
Surface area	sq. cm./gram	30,000
Brightness	photovolt	70
pH (approx.)		7
Dry density	lb./cu. ft.	Min. 14, Max. 15

Cab-O-Sil, a silica aerogel, had the following characteristics, according to the company from whom it was purchased:

Free moisture	percent	0.2 to 1.5
Apparent bulk density:		
Fluffy grade	lb./cu. ft.	2.5 to 3.5
Densed grade	lb./cu. ft.	6.5 to 7.0

Cab-O-Sil, a silica aerogel, had the following characteristics, according to the company from whom it was purchased:--Continued

Bulking value	gal./lb.	0.057
Particle size range	microns	0.015 to 0.020
Silica (SiO_2)	percent	99.0 to 99.7
Surface area	sq. meters/gm.	175 to 200
pH		3.5 to 4.0
Color		White
Refractive index		1.55
Specific gravity		2.1

SG-68, a silica aerogel, had the following characteristics, according to the company from whom it was purchased:

Free moisture	percent	4
Bulk density	lb./cu. ft.	5
Particle size:		
Average	microns	3.5
Range	microns	80% less than 5.5
Silica (SiO_2)	percent	99.+
Surface area	sq. meters/gm.	300
pH		7.4
Color		White
Refractive index		1.46
Specific gravity		2.1

The inert dust was very dirty to apply and very irritating to the workers near the point of application. As the dust fell into the grain stream, a dust cloud arose. This was especially troublesome during windy days, as the operator filling the dust applicator soon became covered with dust. It was necessary for the person applying the dust to cover his nose and mouth with a protective dust-type mask.

Dosage Rates and Application

Perma-Guard and Kenite were applied at a dosage rate of 7 pounds per ton of corn or 196 pounds per 1,000 bushels, and Cab-O-Sil and SG-68 at 1 pound per ton or 28 pounds per 1,000 bushels. There were five replications of each treatment. Cab-O-Sil was applied by hand at the roof top as the corn was augered into the bin. Kenite, Perma-Guard, and SG-68 were applied with a Perma-Guard dust applicator (fig. 2). As the grain fell from the truck and gate, the dust was uniformly added with the applicator delivery auger placed in the grain stream. The dust was further mixed into the grain by the auger screw as the grain was loaded and cascaded into the bins. The first applications of dust caused considerable difficulty by clogging the auger and sometimes stopping it completely. To remedy this, the augering and unloading had to be cut to about one-half speed (500 bushels an hour) for the Kenite, Perma-Guard, and SG-68 applications. Even with the augers running at half capacity, the gas engines were operating under a considerable load with the Kenite and Perma-Guard.

The malathion, at a dosage rate of 1 pint premium-grade 57 percent emulsifiable concentrate per 1,000 bushels, was applied as a spray at the same points as the dusts, at 8 to 12 pounds pressure at the nozzle, in a continuous fan-shaped spray that delivered about 8 gallons per hour. The equipment has been described in an earlier bulletin (17).

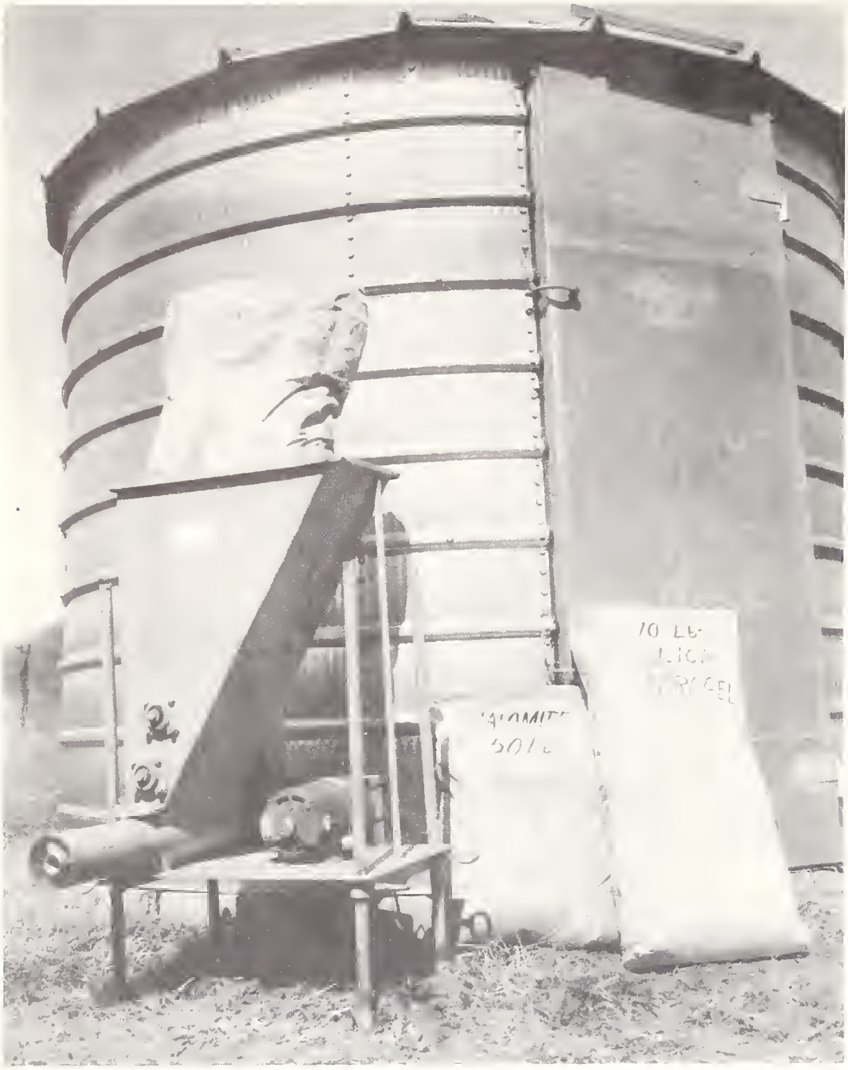

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Figure 2.--Diatomaceous earth applicator used to apply inert dust. Also bags containing inert dust in front of a 500-bushel-capacity steel bin.

Sampling and Processing

Four samples were taken with a 4-foot probe from each 300 bushels before the truck dumped the corn into the auger hopper. The probe was inserted about 2 feet from each corner of the truck. The samples were placed in a closed-top metal can until the bin was filled with corn. By division in a Boerner Sampler, representative samples of 2,000 grams were taken to determine commercial grade of the grain and 1,000 grams for counting numbers of insects.

After treatment, corn samples were taken with a grain trier equipped with extensions and handle. Nine samples were taken from each bin immediately after treatment and at monthly intervals thereafter. The samples were taken vertically from the center of the bin, from 4 feet from the center towards the bin roof door, and from 1 foot from the bin wall beneath the roof bin door. The samples were drawn from the top, middle, and bottom 4 feet of corn at each of the three points. Each sample was examined for living and dead insects, and a moisture determination was made with the Motomco Moisture Meter. Composites of these samples were used for grade determination, insect damage, bioassay (repellency and exposure to test insects), and chemical analysis (malathion only). This was done on a quarterly basis, as conditions would allow, except for the grade determinations submitted once a year.

Grade Determination

About 2,000-gram samples from each bin of corn were sent in plastic-lined cloth bags to Manhattan, Kans., and forwarded to the Kansas City Grain Inspection Office. Two grades were requested on the samples containing silica aerogel. One was to show the grade in the presence of the dust, and the other was to show the grade as if a foreign substance were not present.

Insect Damage

A 1,000-kernel sample was examined from each bin for insect damage. The exit holes or evident insect damage were recorded. The degree of damage was computed by determining the weight of the 1,000 kernels and calculating the percentage by weight of the damage to the kernels.

Malathion Chemical Analysis

About 600 grams from the composite sample for each malathion treatment were sent to Savannah, Ga., for the determination of the malathion residue. The samples were shipped parcel post in plastic-lined bags immediately after they were processed.

Laboratory Bioassay

Exposure to Test Insects

At 3-month intervals, three composite samples from each bin were each placed in a 1-pint jar, three-fourths full, with a 40-mesh bronze wire cloth top. The culture room was maintained at 80° F. ± 2° and a relative humidity of 60 percent ± 5 percent. After 1 week, 50 adult confused flour beetles 28 to 42 days old were placed in one jar from each bin. In another jar were put 50 adult rice weevils 28 to 42 days old. In the third jar from each bin, 30 grams of wheat kernels containing an unknown number of rice weevil larvae 14 to 28 days old were mixed into the corn.

Twenty-one days after the adult confused flour beetles and rice weevils were placed in the jars, the living and dead adults were screened out, recorded, and discarded. The remaining screenings were returned to the jars. Forty-two days after the 21-day examination, the numbers of adult and immature insects in the samples were counted again to determine reproduction. Fifty-six days after the wheat infested with rice weevil larvae was mixed into the treated corn, the adult rice weevils that had emerged were counted.

Repellency

Corn samples used in the repellency tests were taken 1, 3, 6, 9, and 12 months after treatment. At these intervals, 1,200 grams of corn were probe-sampled from each of the treated bins. For control data, 30,000 grams of untreated corn were taken from the check bins. The samples were sent parcel post in polyethylene-lined canvas sacks to Manhattan, Kans., to be tested for repellency.

Repellency tests were conducted using the Laudani-Swank (9) laboratory repellency testing apparatus as modified by Berndt (1). The samples were kept at 80° F. ± 4° and 60 percent ± 4 percent relative humidity for 24 hours to adjust their temperature and moisture content before they were placed into the test apparatus.

Six containers of treated grain and six containers of untreated grain were alternated in the repellency testing apparatus in the constant temperature-humidity chamber. Five hundred adult rice weevils were liberated in the apparatus and allowed to enter the containers of grain as they chose. After 24 hours, the insects were sifted from the grain in each container, counted, and recorded.

RESULTS

Grain Condition

After the corn was treated with inert dust, it became impacted. A person could walk on the surface of the grain without sinking into it. Throughout the observation period the corn treated with inert dust was very difficult to probe. The bins treated with Perma-Guard and Kenite were the most difficult. At times, a 12-pound sledge hammer was necessary to force the probe to the bin floor.

All dusts gave the corn a chalky appearance (fig. 3) and an unnatural feel when handled. Both the malathion-treated corn and the untreated corn retained their bright yellow color.

Insect Populations and Comparative Abundance of the Species of Insects

Insect populations were low in all of the corn immediately after treatment (table 1). Insects increased in number in all dust treatments during the next 2 months, but relatively few were

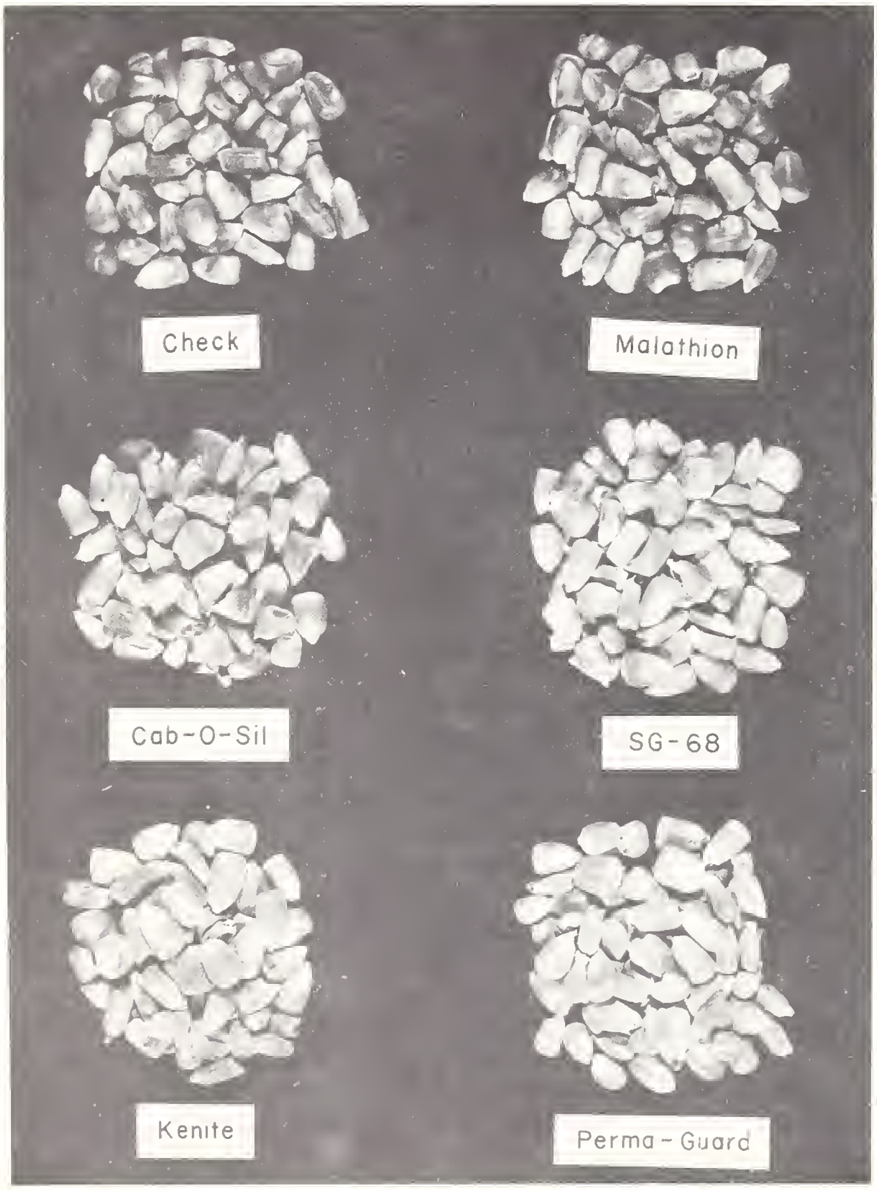

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Figure 3.--Samples of corn after treatment with malathion and inert dusts.

Table 1.--Live insects as percentage of all insects found, by species, and number of live insects found per 1,000-gram sample, in shelled corn treated with inert dust and malathion, 1963-64

Corn treatment and species of insect[1]	1963						1964							
	Before treatment	August	September	October	November	December	January	February	March	April	May	June	July	Total
Perma-Guard:														
Rice weevil..............percent..	100.0	0	100.0	50.0	100.0	0	0	0	0	0	0	0	0	71.9
Cadelle......................do..	0	50.0	0	16.7	0	0	0	0	0	0	0	0	0	8.8
Granary weevil................do..	0	50.0	0	33.4	0	0	0	0	0	0	0	0	0	14.0
Saw-toothed grain beetle.......do..	0	0	0	0	0	0	0	0	0	0	0	100.0	0	5.2
Average number live insects observed................number..	0.4	0.12	0.58	0.42	0.06	0	0	0	0	0	0	0.06	0	--
Kenite:														
Rice weevil..............percent..	80.0	100.0	85.7	100.0	100.0	100.0	0	0	0	0	0	50.0	0	83.6
Red flour beetle..............do..	20.0	0	0	0	0	0	0	0	100.0	0	0	50.0	0	11.5
Granary weevil................do..	0	0	14.3	0	0	0	0	0	0	0	0	0	0	4.9
Average number live insects observed................number..	1.0	0.04	0.46	0.26	0.20	0.06	0	0	0.06	0	0	0.12	0	--
Cab-O-Sil:														
Rice weevil..............percent..	100.0	100.0	100.0	100.0	0	0	0	0	0	0	0	0	100.0	100.0
Average number live insects observed................number..	0.60	0.12	0.66	1.60	0	0	0	0	0	0	0	0	0.08	--
SG-68:														
Rice weevil..............percent..	100.0	50.0	100.0	83.3	0	0	100.0	0	0	0	0	0	0	95.3
Granary weevil................do..	0	50.0	0	16.7	0	0	0	0	0	0	0	0	0	4.7
Average number live insects observed................number..	0.60	0.12	1.22	0.40	0	0	0.06	0	0	0	0	0	0	--
Malathion:														
Rice weevil..............percent..	100.0	100.0	100.0	100.0	0	0	0	0	0	0	0	0	0	100.0
Average number live insects observed................number..	0.20	0.04	0.06	0.14	0	0	0	0	0	0	0	0	0	--
Check:														
Rice weevil..............percent..	33.3	44.4	68.8	85.7	89.8	50.0	0	33.3	0	50.0	13.3	15.2	17.6	62.8
Saw-toothed grain beetle.......do..	66.7	44.4	13.8	1.9	0	0	0	0	0	0	73.3	27.3	44.7	16.1
Red flour beetle..............do..	0	11.1	2.6	7.1	0	22.2	0	0	0	0	6.7	42.4	14.3	7.3
Foreign grain beetle...........do..	0	0	1.9	0.7	0	0	0	0	0	0	0	3.0	3.7	1.4
Rusty grain beetle............do..	0	0	8.6	4.4	6.4	27.8	100.0	66.7	100.0	0	6.7	9.0	19.3	10.5
Hairy fungus beetle...........do..	0	0	0.6	0.3	0	0	0	0	0	0	0	0	0	0.2
Indian-meal moth..............do..	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0.1
Cadelle......................do..	0	0	1.2	0	0	0	0	0	0	0	0	3.0	0	0.3
Granary weevil................do..	0	0	1.2	0	0	0	0	0	0	50.0	0	0	0.4	0.4
Red-horned grain beetle........do..	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0.1
Average number live insects observed................number..	0.80	0.40	3.38	7.40	5.08	0.42	0.08	0.12	0.06	0.04	0.28	0.74	5.38	--

[1] The scientific names of these insects are listed in U. S. Dept. Agr. Farmers' Bulletin 1260 (rev.) June 1965.

found thereafter. Only three bins of malathion-treated corn showed evidence of infestation, and in each instance the number was not more than 0.7 insect per 1,000 grams. Populations in the check bins were higher than in the treated bins every month throughout the sampling period. It was necessary to fumigate one of the check bins after the November sampling.

The monthly samples drawn from the bins were screened, and the number and species of stored-grain insects were recorded. The comparative abundance of the different species is given in table 1, expressed as percentages of the total number of insects found during each month.

The rice weevil was the predominant species in all of the treatments, including the checks, even though the corn was also artificially infested with the red flour beetle.

Commercial Grade

The test weights of all corn samples were less after treatment with inert dust (table 2). Diatomaceous earth reduced test weight an average of 4.6 pounds per bushel and silica aerogel about 4.1 pounds. Weight reduction was not evident in the malathion and check treatments. One

Table 2.--Commercial grade and grade factors in corn before and after treatment with inert dust or malathion, and in untreated corn (average of 5 bins each)

Treatment and time of grading	Grade	Test weight	Moisture content	Odor	Total damage	Foreign material
	Number	Pounds	Percent		Percent	Percent
Perma-Guard:						
Before treatment..........	2	57.6	13.7	OK	4.3	1.3
1 month after.............	3	52.9	13.0	OK	3.2	0.5
13 months after...........	3	53.4	12.8	OK	5.1	1.0
Kenite:						
Before treatment..........	2	57.6	13.9	OK	4.9	1.2
1 month after.............	3	53.1	13.2	OK	3.6	0.9
13 months after...........	3	53.6	12.9	OK	5.5	1.5
Cab-O-Sil:						
Before treatment..........	2	57.6	14.0	OK	4.6	1.3
1 month after.............	[1] 3	53.8	13.5	OK	3.5	0.4
13 months after...........	[1] 2	54.7	13.1	OK	4.5	0.8
SG-68:						
Before treatment..........	2	57.3	13.9	OK	3.9	1.5
1 month after.............	[1] 3	52.9	13.2	OK	3.5	0.7
13 months after...........	[1] 2	53.3	12.8	OK	5.0	1.0
Malathion:						
Before treatment..........	2	57.5	13.9	OK	3.8	1.2
1 month after.............	2	57.1	13.8	OK	3.7	0.7
13 months after...........	2	56.9	13.2	OK	4.2	0.8
Check:						
Before treatment..........	2	57.4	13.9	OK	4.6	0.8
1 month after.............	2	57.3	13.8	OK	3.3	0.5
13 months after	[2] 3	56.7	13.0	OK	6.6	0.7

[1] Because of unknown foreign substance this sample was graded "Sample grade." Grade shown as if foreign substance were not present.

[2] Two bins graded "weevily."

month after treatment, the lowered test weights placed the dust-treated corn into a lower commercial grade.

All of the dust-treated corn had lower moisture readings after treatment. This lowered moisture reading was not because of actual reduction of moisture in the corn but was the result of an inaccurate reading by the moisture meter, caused by the physical effects of the dust on the corn.

Insect-Damaged Kernels

Table 3 shows data on insect damage. One thousand kernels taken from each bin of corn during October 1963 indicated that the corn had a low percentage of damaged kernels. There were no marked increases during the observation period in damage in the corn that received the dust or malathion treatments. Insect damage in the untreated checks was increased considerably in the July 1964 samples. Samples from two of the bins showed about 3.5 percent damage by weight.

Table 3.--The average percent by weight of insect damage to kernels in corn treated with inert dust and malathion, and in check bins of untreated corn (average of 5 bins)

Treatment	October 1963	December 1963	March 1964	July 1964
	Percent	Percent	Percent	Percent
Perma-Guard	0.14	0.44	0.26	0.26
Kenite	.18	.30	.10	.20
Cab-O-Sil	.20	.16	.14	.18
SG-68	.30	.46	.10	.28
Malathion	.18	.34	.20	.16
Check	.16	.94	.54	1.52

Malathion Residue Analyses

Data from residue analyses are in table 4. The malathion recovered 1 month after treatment in October 1963 and at intervals to September 1964 showed that about one-fifth of the malathion applied was recovered 1 month after treatment, and the residues remained almost constant for 1 year.

Table 4.--Malathion residue in shelled corn that had received an intended deposit of 11.1 p.p.m.[1]

[Corn stored in 3,250-bushel standard USDA circular, metal bins. Watseka, Ill.]

Bin designation	October 1963	January 1964	May 1964	July 1964	September 1964
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
C-18	2.0	2.0	2.1	1.6	1.5
C-38	2.1	2.5	3.5	2.2	1.9
D-36	(3)	1.7	2.6	1.5	1.8
E-34	1.4	1.6	2.4	1.7	1.3
F-23	2.6	2.5	3.7	2.0	2.4
Average	2.0	2.1	2.9	1.8	1.8

[1] Composite of 9 samples from each bin on each date.

[2] One month after treatment.

[3] Sample lost.

Laboratory Bioassay

Adult Rice Weevil Mortality

Table 5 shows the mortality of adult rice weevils when confined for 21 days in treated samples of corn. Mortality was complete 3 months after treatment with SG-68 or malathion.

Table 5.--Summary of mortality, reproduction, and emergence of rice weevils and confused flour beetles confined in samples of shelled corn treated with inert dust and malathion, and untreated checks (means of 5 bins)

Treatment and time of examination after treatment	Mortality		Reproduction		Emergence of immature rice weevil	
	Rice weevil	Confused flour beetle	Rice weevil	Confused flour beetle	Live	Dead
	Percent	Percent	Number	Number	Number	Number
Perma-Guard:						
3 months.........	90	29	33	5	13	72
6 months.........	57	3	25	1	4	26
9 months.........	64	11	71	4	56	54
12 months.........	31	9	21	1	33	43
Kenite:						
3 months.........	97	62	14	3	5	33
6 months.........	77	22	21	1	3	28
9 months.........	43	4	55	9	47	61
12 months.........	45	11	32	2	24	66
Cab-O-Sil:						
3 months.........	56	49	41	9	26	34
6 months.........	52	41	47	1	18	14
9 months.........	12	15	53	5	109	12
12 months.........	52	48	17	1	81	23
SG-68:						
3 months.........	100	71	7	1	5	37
6 months.........	96	85	6	0	5	30
9 months.........	72	11	28	2	48	57
12 months.........	94	60	7	1	20	49
Malathion:						
3 months.........	100	42	3	2	1	80
6 months.........	100	62	0	1	0	34
9 months.........	99	6	2	0	4	86
12 months.........	93	8	11	1	44	46
Check:						
3 months.........	4	3	318	54	212	1
6 months.........	5	2	122	20	29	3
9 months.........	5	1	178	29	172	2
12 months.........	2	3	140	2	132	1

Less kill was evident in corn treated with Cab-O-Sil, Perma-Guard, and Kenite. With the exception of SG-68 and malathion, the mortalities in all treated corn were very low at 12 months. Only malathion caused mortalities of more than 90 percent at all test periods.

Adult Confused Flour Beetle Mortality

Three months after treatment, the mortalities of the confused flour beetle were much lower than the rice weevil mortalities (table 5). The SG-68 and Kenite appeared to be the most effective treatments. Six months after treatment the mortality dropped in all of the corn except that treated with malathion and SG-68. Nine months after treatment the mortalities were lower in all treatments, with little difference among any of the treatments. Mortalities were higher at 12 months than at 9 months in all treatments except Perma-Guard.

Reproduction of Rice Weevil and Confused Flour Beetle

Reproduction of both the rice weevil and confused flour beetle was retarded in all of the treated corn. The malathion was the most effective in limiting the progeny of these two species.

Emergence of Immature Rice Weevils

Weevils emerging from the wheat placed in the treated corn 3 and 6 months after treatment had a higher percent of mortality than those emerging from wheat placed in the corn 9 and 12 months after treatment. All treatments with dust or malathion had a pronounced inhibiting effect on weevil population development over a period of two generations.

Repellency

The data obtained in the repellency tests are summarized in table 6. The highest percentage of repellency to rice weevils at the initial observations was 80 percent from the Kenite-treated corn; next highest was the Perma-Guard-treated corn with 74.12 percent repellency. SG-68 and Cab-O-Sil did not repel insects as strongly as the two diatomaceous earths.

While the repellency percentages were quite erratic through the passage of the year, the repellency of the corn treated with Perma-Guard and Kenite remained high. Kenite-treated corn appeared to lose repellency gradually over a period of 9 months, only to have a higher repellency value at 1 year than at the initial observation.

The initial repellency of SG-68 was 66.60 percent, and of the Cab-O-Sil, 31.86 percent. Corn treated with the two silica aerogels gradually lost repellency during the year. The repellency of the corn treated with Cab-O-Sil dropped from 31.86 percent to 17.16 percent, an apparent loss of nearly half the original repellency.

The malathion-treated corn did not exhibit any appreciable repellency through the observation period.

Table 6.--Repellency to adult rice weevils exhibited by treated corn taken from test bins at periodic intervals (average of 5 bins)

Treatment, rate of application, and time of examination after treatment	Insects entering corn		Repellency[1]
	Treated bins	Untreated bins	
	Number	Number	Percent
Perma-Guard, 7-lb. per ton:			
1 month	254	1,709	74.12
3 months	274	1,968	75.54
6 months	249	1,613	73.24
9 months	203	2,051	81.98
12 months	409	2,014	66.24
Kenite, 7-lb. per ton:			
1 month	172	1,549	80.00
3 months	277	1,879	74.30
6 months	289	1,895	73.52
9 months	460	2,073	63.66
12 months	161	1,986	85.00
Cab-O-Sil, 1-lb. per ton:			
1 month	590	1,148	31.86
3 months	783	1,484	30.92
6 months	918	1,201	13.36
9 months	922	1,404	20.72
12 months	1,013	1,433	17.16
SG-68, 1-lb. per ton:			
1 month	337	1,682	66.60
3 months	550	1,679	50.64
6 months	706	1,422	33.64
9 months	611	1,432	40.18
12 months	517	2,116	60.72
Malathion, 1 pint of 57-percent EC per 1,000 bu.:[2]			
1 month	838	1,119	17.72
3 months	--	--	--
6 months	1,066	1,263	8.44
9 months	1,335	1,319	-0.62
12 months	1,130	1,357	9.12

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[1] See Laudani et al. (8) for method of calculating repellency.

[2] See table 4 for malathion residue at time of testing.

FINDINGS

Although this work has not been completed, the following points were evident from the first year of the study:

1. Diatomaceous earth, silica aerogel, and malathion at the dosages used in this test gave a high degree of protection from insect infestation or damage for 1 year.
2. Treatment of corn with silica aerogel or diatomaceous earth lowered the test weight from 3 to 5 pounds per bushel.
3. Moisture readings were lowered by the use of diatomaceous earth or silica aerogel. This lowered reading was due to the physical action of the dust on the corn rather than to actual reduction in moisture.

4. Corn treated with silica aerogel was graded "sample grade."
5. Corn treated with diatomaceous earth exhibited a higher degree of repellency to the rice weevil than corn treated with silica aerogel or malathion.
6. Laboratory bioassay tests indicate the superiority of malathion over the dust treatments in causing mortality, inhibiting reproduction, and reducing emergence of test insects. This is especially true with the rice weevil, the predominant species in the samples taken from the bins.
7. After treatment with dust, especially diatomaceous earth, the corn became impacted and was very difficult to probe.
8. Movement of corn through the augers had to be reduced by at least one-half to prevent plugging of the conveyors and damage to equipment.
9. Dust in the air caused an open air-cooled electric motor on the dust applicator to overheat and burn out after moving 30,000 bushels. A totally enclosed motor would be desirable.
10. The approximate costs of material to treat 1,000 bushels of corn were $23 for the silica aerogels, $12 for the diatomaceous earths, and $1 for malathion. This does not include freight charges.

DISCUSSION

This study is to be continued at least another year, as insect populations are still low in all of the treated corn. Increases in natural insect populations are not likely to occur until the corn warms in the following spring and summer.

Judging by the results of the bioassay tests in the laboratory, the treatments declined in effectiveness as the year continued. After 12 months the mortalities of the insects were low in the corn treated with the two diatomaceous earths and with the Cab-O-Sil. Reproduction was high. However, the natural populations in the corn mass in the bins remained at a low level all during this period. In the laboratory, the insects were confined on the dust-treated corn without a free choice of leaving or remaining. In the natural populations, where the insects were able to leave the dusty corn and infest bins of corn more attractive to them, repellency should be considered as a factor contributing to the low populations.

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